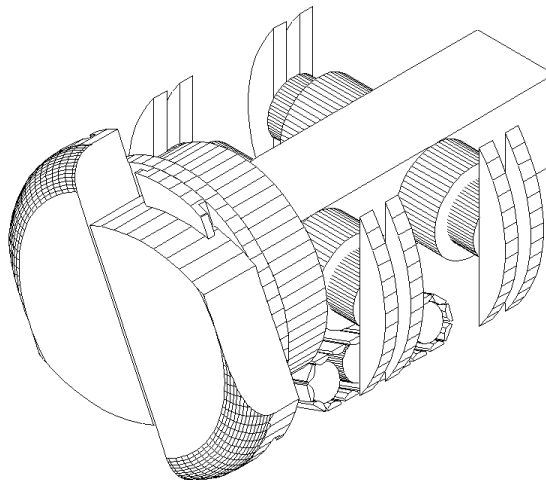
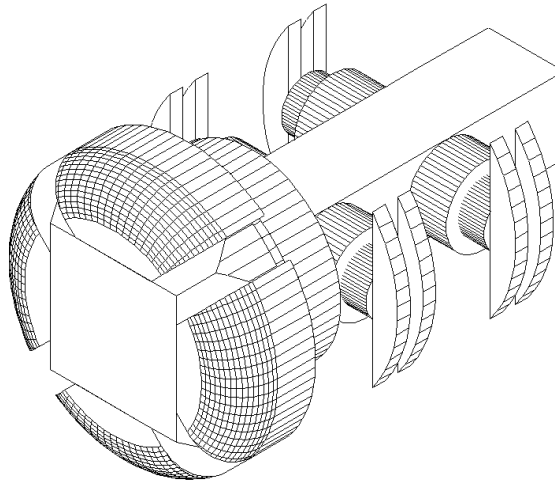
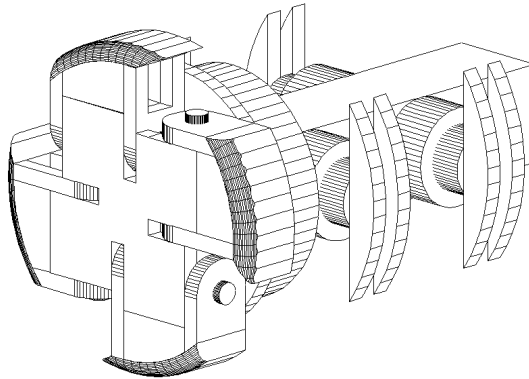


# Concepts for a Retractable TBM for Remote-Control Tunneling

*Bill Foster, Mike May*  
*March 15, 1999*



## Goals:

- Greatly reduce in-tunnel labor
- Repair/Replacement of TBM from surface
- Increase predictability of tunneling costs
- Permit long drives from a single location
- Reduce capital costs for TBM backup eqpt.
- Direct access to face when unexpected ground conditions encountered
- Demonstrate system that can be scaled to 500km circumference ring.

## Methods:

- Unimproved tunnel during construction: no rails, conveyors, electrical, water...
- Automatic, containerized muck haulage on rubber-tired remote-control vehicles
- Retractable TBM with self-contained power system (batteries, fuel cells...)
- Possibility of flat-cut floor behind TBM

***See also companion note on automated TBM mucking with battery powered wheeled vehicles:***

[http://www-ap.fnal.gov/VLHC/vlhcpubs/pubs1-100/85/battery\\_tunneling.pdf](http://www-ap.fnal.gov/VLHC/vlhcpubs/pubs1-100/85/battery_tunneling.pdf)

# Tunnel Description

- 3m diameter tunnel in Dolomite
- 150m average depth
- 34km ring excavated in 2 x 17km drives from single point at Fermilab
- All muck removal via vehicle ramps (which are later used for magnet installation and beam transfer lines)
- Ring slopes up gently away from Fermilab to ease water drainage during tunneling
- Large experimental pit on FNAL site (separate project)
- On-site straight section ~3km long is dual side-by-side tunnels separated by ~10m
- Air shaft/emergency egress every ~5 miles (three off-site surface penetrations)

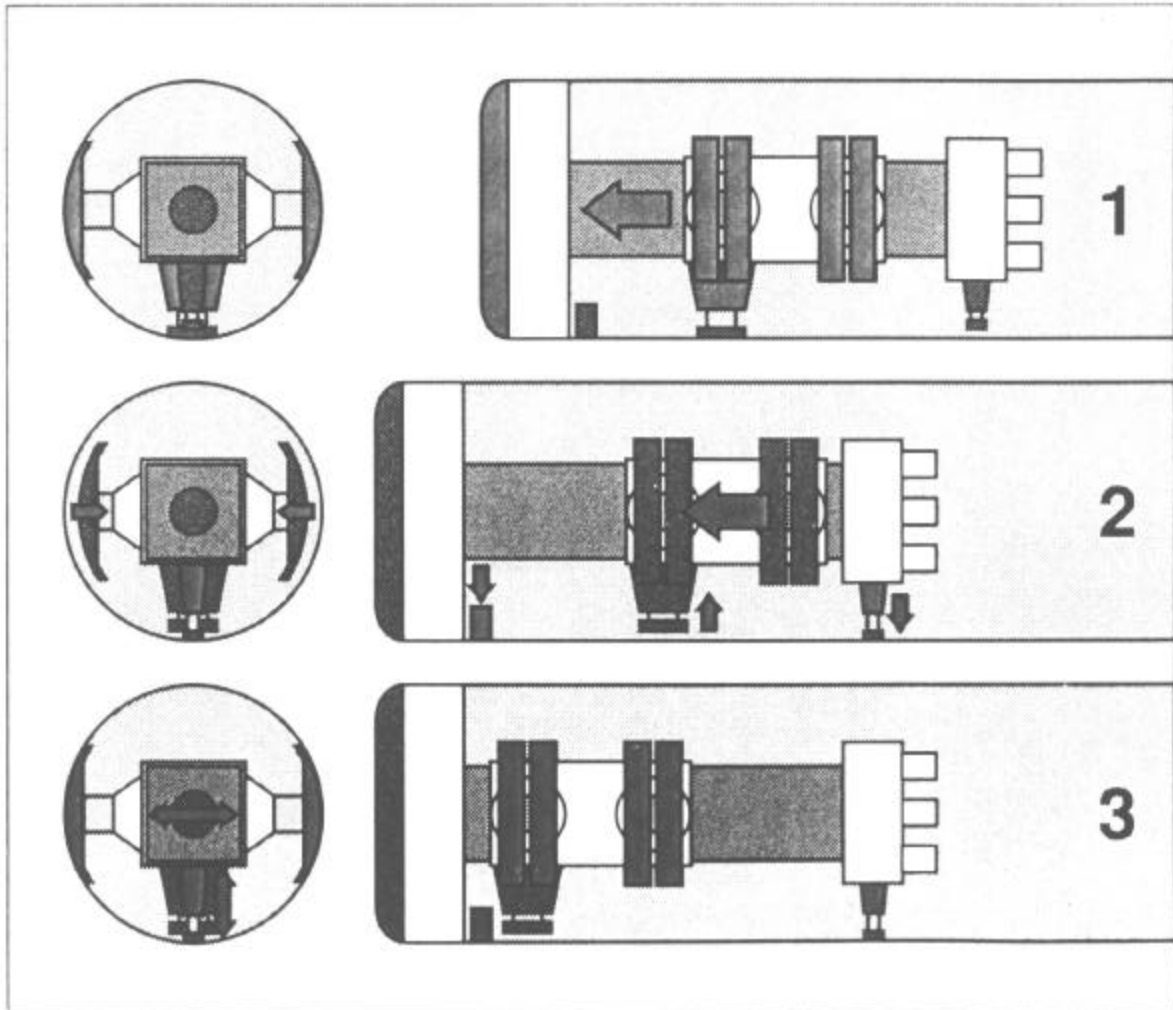
# **Key Component: Retractable TBM**

- Standard "open" machine with disk cutters and hydraulic grippers
- Machine on caterpillar tracks which are only used for transport
- Cutterhead radius can be reduced 8-12" for extraction of machine
- Grippers must retract 8-12" as well
- Rear-changing cutters not necessary
- Can be towed out by muck car, or self-propelled via hydraulic motors on treads
- Electric power from fuel cells or batteries provided by mucking vehicles
- Water for cooling & dust control provided by tank on mucking vehicle

## **5 km/h travel rate (target)**

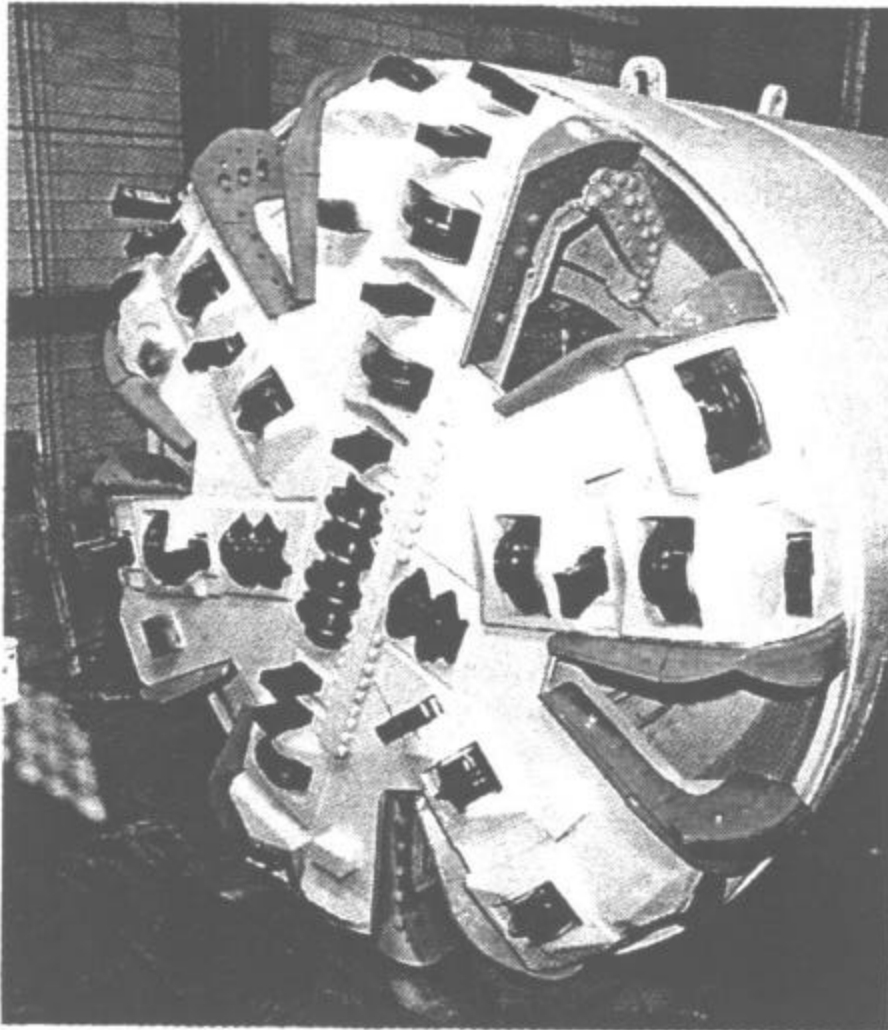
- Caterpillar tracks routinely go >15kph
- TBM can be pulled out & replaced in <1 shift even at far end of 17km drive
- Can be pulled out & fixed <1 hour early in drive while system is being debugged

- 1) Bore 2) Regrip  
3) Ready to bore

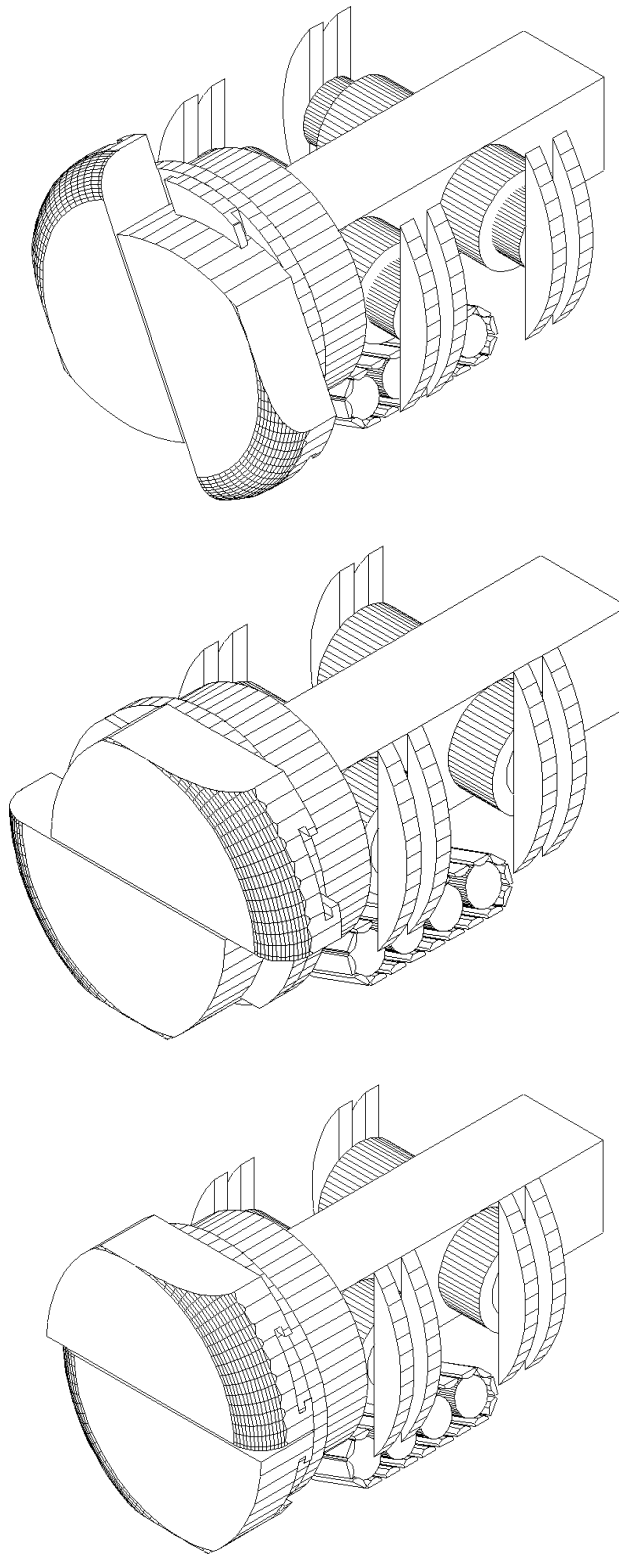


## Standard "Open" TBM Design (from Robbins/Boretec Catalog)

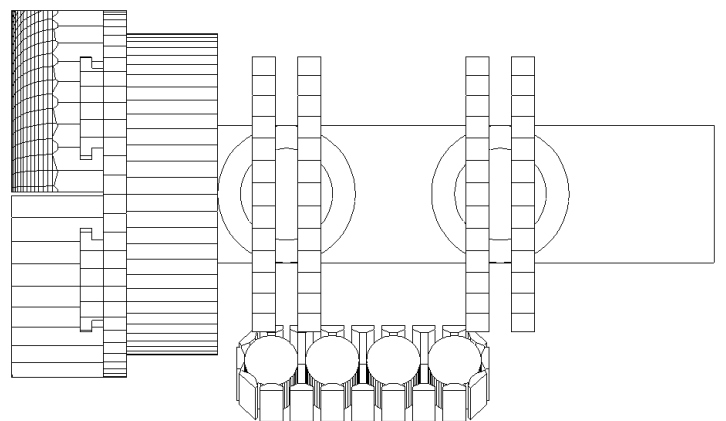
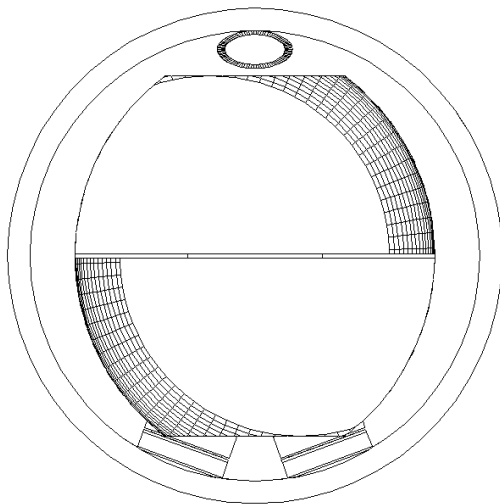
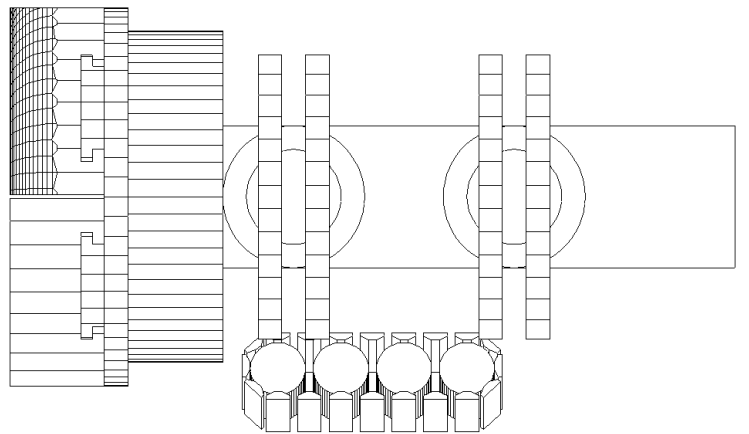
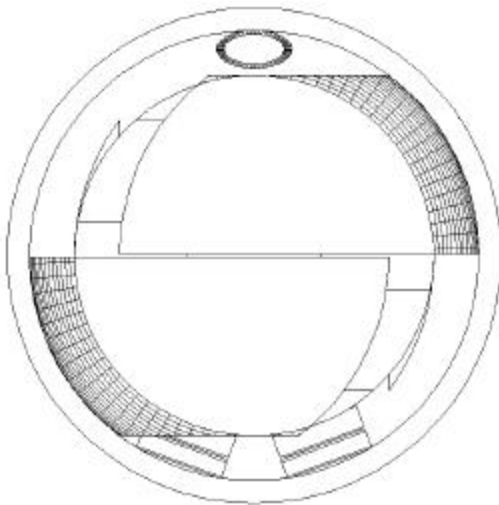
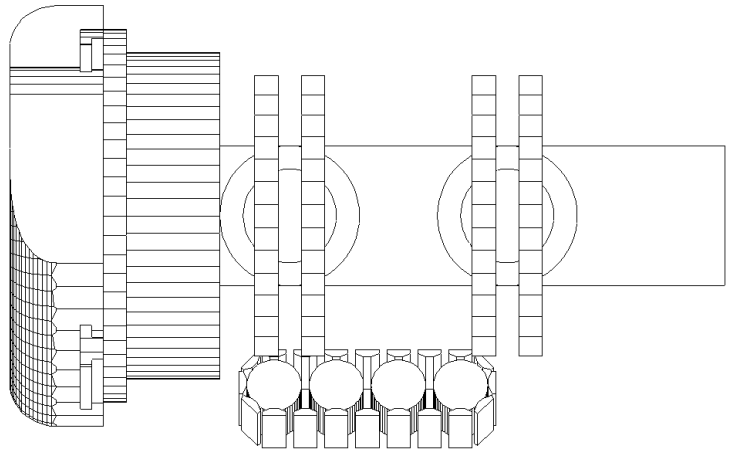
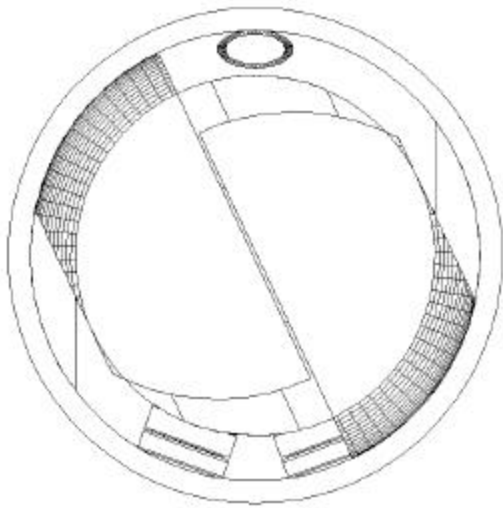
# Typical TBM head (Lovat)



**H**ard rock machine cuttingheads. The location and combination of the mixed-face cuttinghead's ripper and disc cutters can be reconfigured for maximum excavation as ground conditions vary.

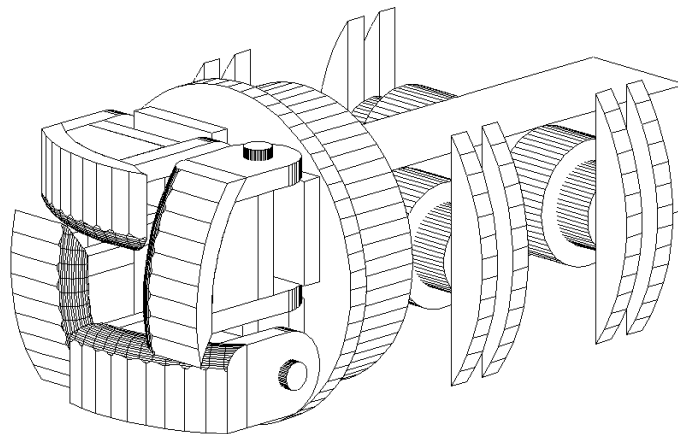
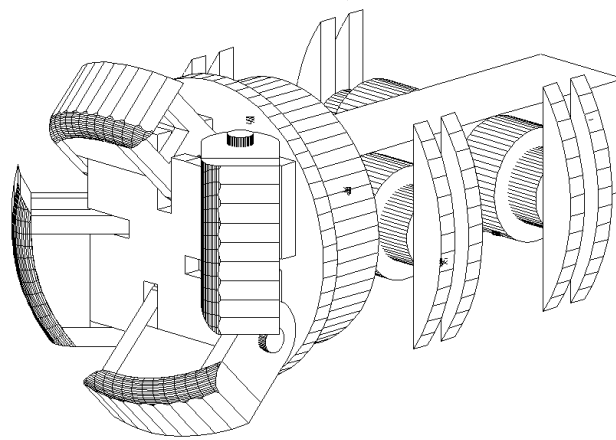
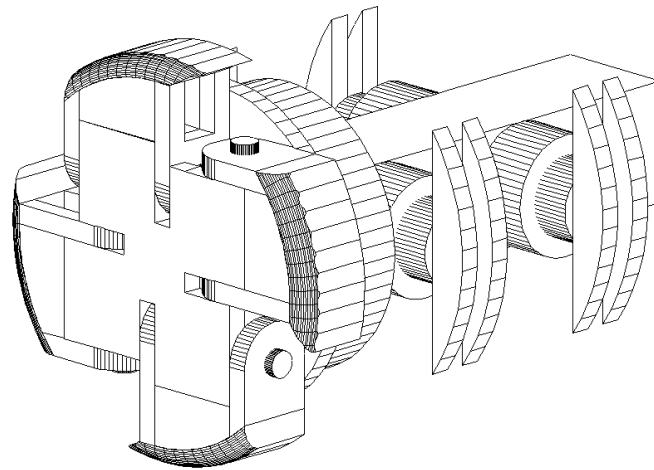


Concept A – The cutting head is split into two sections which slide inwards to retract TBM.

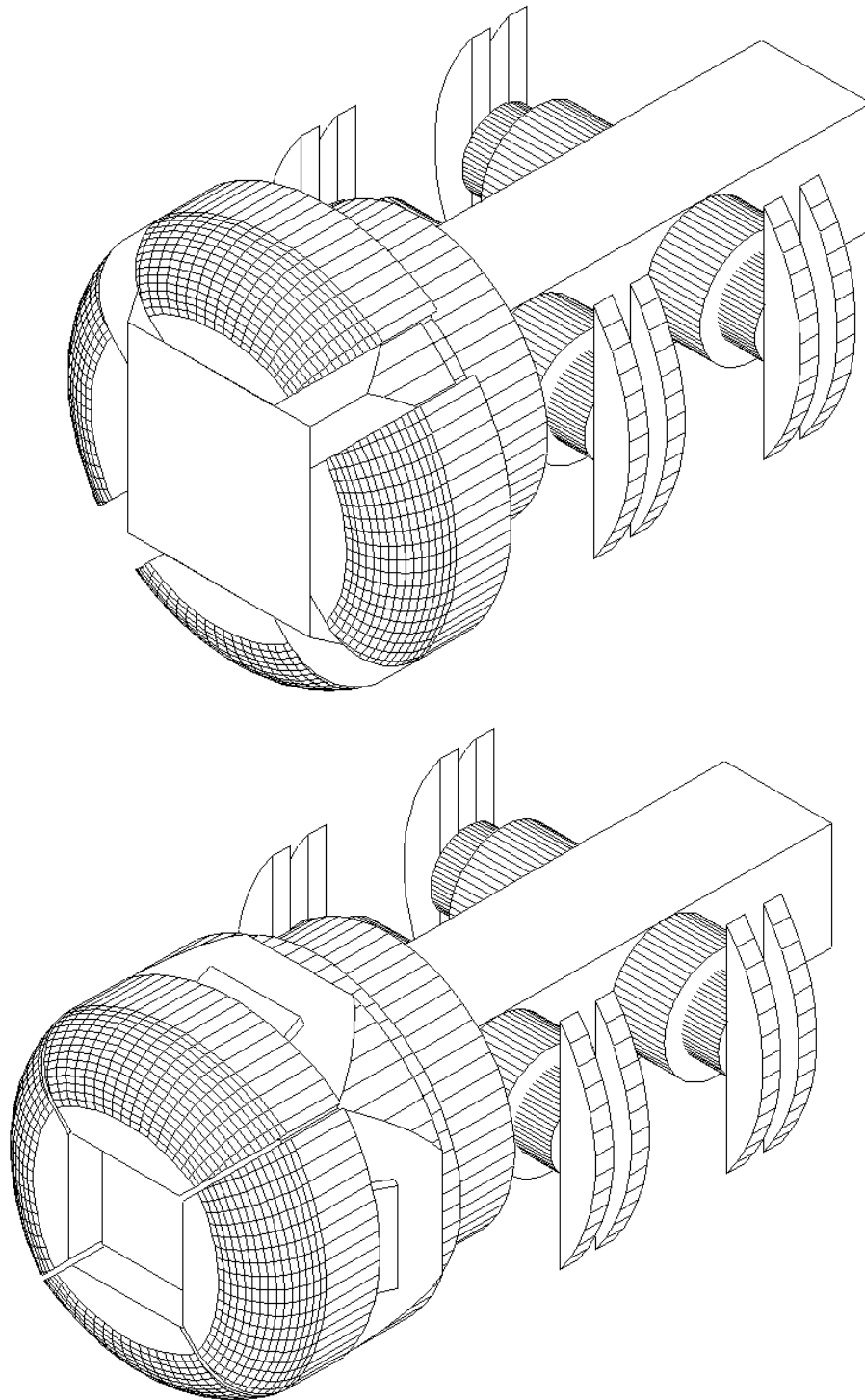


## Concept A - Front and Side Views





Concept B – 4 "Blades" fold forward towards cutting face to retract TBM.



Concept C – 4 "petals" slide forward towards cutting face to retract TBM.

# **Bare Essential Utilities in Tunnel**

- Bag line air hose
- "Leaky Cable" Radio link to equipment
- Routine rock bolting (automated)
- Survey monuments (w/ rock bolting)
- Local survey system to keep TBM oriented

## **Reasons for Manned Entry**

- Survey
- RF Link Extension
- Air Bag Line Extension
- Rock Bolt Inspection
- (Rarely) fixing stuck remote-control vehicle which can't be towed out with muck car

## **Conditions for Manned Entry**

- Remote Controlled Muck Cars Removed from Tunnel and Locked Out.
- TBM Extracted to Surface and Locked out.
- Small Electric Vehicle with protective cage, air supply, work lights and safety equipment
- Spare Vehicle available at surface.

# Dealing with Messes

## I. Groundwater Inrush

- Pull back TBM and let water flow out (downhill to FNAL) until it subsides
- Send in remote-control grouting/rockbolting drill to stabilize ground & seal leaks (these rigs are commercially available)
- Send TBM back in to resume operations

## II. Rock fall traps TBM & Muck Car

- Send in remote-controlled grouting/rockbolting rig to pulverize debris and stabilize roof
- Spare muck car with scoop on front scrapes up debris
- Manned access may be necessary to repair bagline and RF link

## III. Potholes

- Fill them using grouting/rockbolting rig
- Grind smooth with TBM head (or corner-cutter machine) if needed.

## Other Beneficial System Aspects

- Repairs in surface shop: "fleet maintenance" not general contractor situation
- Possibility of spare machine to increase TBM availability and decrease urgency of repairs (spare machine shared between 2 drives)
- Can modify cutter head for unexpected ground conditions

## Other Documents

- GW Foster "Battery Powered TBM" note:  
[http://www-ap.fnal.gov/VLHC/vlhcpubs/pubs1-100/85/battery\\_tunneling.pdf](http://www-ap.fnal.gov/VLHC/vlhcpubs/pubs1-100/85/battery_tunneling.pdf)  
which also describes wheeled-vehicle mucking scenario.
- Mike May note on "corner cutter" machine to grind a flat floor in a round tunnel (in preparation).